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Apple Sorting

METHODS AND EQUIPMENT

MARKETING RESEARCH REPORT No. 230

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U. S. Department of Agriculture
Washington, D. C.

Other reports covering the handling, storing, and packing of apples issued by the U. S. Department of Agriculture include:

The Comparative Efficiency of Current Methods and Types of Equipment Used for Receiving Field Boxes of Apples at Storage Houses in the Pacific Northwest Area. January 1952.

A Portable Mechanical Lift for High-Piling and Breaking Out High-Piled Boxes of Apples. May 1952.

Apple Handling Methods and Equipment in Pacific Northwest Packing and Storage Houses. Mktg. Res. Rpt. No. 49. June 1953.

Methods and Costs of Loading Apples in the Orchard in the Pacific Northwest. Mktg. Res. Rpt. No. 55. January 1954.

Handling Empty Apple Boxes in Pacific Northwest Packing and Storage Houses. Mktg. Res. Rpt. No. 71. June 1954.

Innovations in Apple Handling Methods and Equipment. Mktg. Res. Rpt. No. 68. January 1955.

The Effect of Apple Handling Methods on Storage Space Utilization. Mktg. Res. Rpt. No. 130. July 1956.

Storage and Cooling Capacity in Apple Storages in the Wenatchee-Okanogan, Washington, District. AMS–196. July 1957.

Comparative Costs of Handling Apples at Packing and Storage Plants. Mktg. Res. Rpt. No. 215. March 1958.

Handling and Storage of Apples in Pallet Boxes. AMS–236. April 1958.

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
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PREFACE

This report is based on a study which is part of a larger project covering research on apple sorting, sizing, and packing operations, conducted under contract with the Fruit Industries Research Foundation, research agent of Washington State Apple Commission. The report covers the findings on apple sorting. Other reports will cover sizing, packing, and other packing room operations; also, a summary covering all packing room operations is planned. This study is part of a broad program of continuing research designed to increase the efficiency of the physical handling of farm commodities during marketing.

Some of the results of this research are now available in summary form through the U. S. Department of Agriculture film entitled "Apple Packing Methods." This film may be purchased through the Motion Picture Service, Office of Information, U. S. Department of Agriculture, Washington 25, D. C. A print of this film may be borrowed from (1) Agricultural Extension Service, Colorado A. & M. College, Fort Collins, Colo.; (2) Visual Aids Service, University of Illinois, 713-1/2 South Wright Street, Champaign, Ill.; (3) Agricultural Extension Service, College of Agriculture, Cornell University, Ithaca, N. Y.

The research contract under which this study was made was administered by William H. Elliott, head, handling and facilities research section, Transportation and Facilities Branch, Marketing Research Division, Agricultural Marketing Service.

Frederick C. Winter, associate professor of industrial engineering, Columbia University, consultant to the Transportation and Facilities Branch, and Joseph F. Herrick, Jr., agricultural economist, Transportation and Facilities Branch, gave guidance and helpful suggestions on methods used in conducting the research and preparing the manuscript.

William C. Dower, of the Fruit Industries Research Foundation, gave valuable service in preparing the report. The officers and managers of the Yakima County Horticultural Union, and especially Barney Benedictson, manager of the Naches plant, also gave assistance and cooperation.

The Washington State apple storage and packing plants made their facilities available and gave valuable assistance.

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Apple Sorting METHODS AND EQUIPMENT

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SUMMARY

In preparing fresh apples for market, sorting by grade is a necessary and costly operation. If packinghouse operators could increase the output of sorters a sizable saving could be realized, which in turn could be passed on to consumers or growers, or both. Consequently, the main objectives of this study were (1) to develop and test new sorting methods and devices for existing sorting equipment, and (2) to develop and test a new sorting table which would substantially reduce costs of sorting.

Initially three types of sorting tables were studied: (1) The belt table, (2) the spiral-roll table, and (3) the reverse-roll table. On the belt table all fruit is lifted by the sorters and placed on runoff belts; at the end of the table the unsorted fruit is shunted onto a smaller belt and returned to the head of the table. On the spiral-roll and reverse-roll tables, one grade of fruit is allowed to run off the end of the table onto a conveyor belt leading to the sizer.

In these studies, the type of sorting table, the quality and size of fruit, the physical capacity of sorters, the rate at which apples are presented for inspection, and the number of grades sorted were considered in determining the relative efficiency of the three sorting tables. The reverse-roll sorting table was found to be the most efficient, and was modified to increase sorting efficiency.

Major modifications included installation of (1) sorting lanes, (2) variable forward speed of the rolls, and (3) a cull disposal chute beside each sorter. When the reverse-roll table was so modified, workers were able to sort 10 to 46 percent more fruit per hour than on the standard reverse-roll table. These improvements can be adapted to the other tables, but the resulting increase in efficiency will not be as great.

As a result of these studies a new "float-roll" table was designed, constructed, and tested. This table, about 12 inches wider than any commercial table now in use, was built so that both rotation speed and forward speed of the rolls could be controlled. The rolls carried or "floated" the apples in full view of the sorters. Tests showed that about 17 percent more apples per hour could be sorted on the new table than on the improved reverse-roll table.

The cost of labor for sorting 1,000 boxes of apples of 3 sizes containing 30 to 50 percent of low-grade fruit was lowest for the new float-roll table, and highest for the belt table. For 1,000 boxes of size 125 apples (2¾ inches in diameter) containing 50 percent of low-grade fruit, the total cost was $36 for the float-roll table, $62 for the belt table, $46 for the spiral-roll and standard reverse-roll tables, and $42 for the improved reverse-roll table. Differences in costs of owning and operating the 5 tables were small. Consequently, differences in efficiency of the sorters were largely responsible for the wide differences in total sorting costs for the 5 tables.

A packinghouse operator using an old-type sorting table could recover the initial cost of a float-roll sorting table in a short time. For instance, assuming that his present sorting table is fully depreciated (has no book value), an operator sorting 50,000 boxes of unpacked apples a season on a belt-type table could recover the initial cost of a float-roll table, about $1,578, in approximately 1½ years. He could recover the cost of replacing a spiral-roll or reverse-roll table in about 3½ years. The time required to recover the initial cost of the float-roll table would be shorter for operators who sort larger volumes.

Before replacing a fully depreciated sorting table with a new float-roll table, an operator should consider other cost elements that may be involved. To use the extra capacity of the float-roll table, some operators may have to invest additional capital in more efficient sizing and packing equipment. The

decision to buy additional equipment should be based on whether volume of business is expected to increase, decrease, or remain the same in the future. Small-volume packers should consider adopting more efficient sorting methods and making alterations, such as those described in this report, in existing equipment before investing additional capital in new equipment.

BACKGROUND OF STUDY

One of the most costly phases of work connected with packing and warehousing apples is that of sorting or grading the fruit. At this point the color, appearance, and quality of the pack are evaluated. Each season in Washington State, where this research was conducted, enough apples to fill approximately 40 million boxes pass over the sorting tables of more than 250 packing plants. At each of these tables 6 to 12 people are employed, depending on the type of table and size of packing operation. Operators of packing plants could realize substantial savings if they could reduce the number of workers required to perform this operation, or increase the output per worker.

During the past few years the Pacific Northwest apple industry has experienced changes in plant layout, handling equipment, and methods, as well as a change in the type of pack.

In the future, emphasis will be placed on more precise grading of apples, not only in the Pacific Northwest but in other major apple producing areas.

Sorting, sizing, and packing apples are continuous operations. They are performed in succession; they must be continuous if delays are to be avoided. The entire operation cannot proceed faster than the slowest segment.

The sorting operation essentially consists of 4 elements: (1) Inspecting an apple to ascertain its grade, (2) picking up the apple, (3) transferring it to a conveyor belt, and (4) releasing it on the conveyor belt. The different ways the work is performed are variations or combinations of these 4 elements.

Two different types of sorting tables determine the way these elements are combined. On what is commonly known as the no-runoff table, all fruit is lifted from the table and placed on belts which carry the apples to the sizing equipment. On the runoff table, only part of the fruit is lifted and placed on conveyor belts; apples of one grade remain on the table and are conveyed directly to the sizing line.

The objectives of this study were (1) to determine the comparative efficiency of various methods and types of equipment currently used for performing the sorting operation, (2) to develop and test improved method for using present equipment, and (3) to introduce and test, under actual operating conditions, new types of sorting equipment.

TYPES OF SORTING TABLES

When this research was undertaken, three types of apple sorting tables were in use in the Pacific Northwest. These were the conveyor-belt, spiral-roll, and reverse-roll tables. Because of the many variable operating conditions in packing plants, opinions differed among packinghouse operators as to the relative merits of these sorting tables.

Conveyor-Belt Table

The conveyor-belt table, shown in figure 1, is composed of two belts on either side of the table. A broad main belt conveys the fruit past sorters who pick up the apples and place them on smaller belts running above the sorting table, which convey them to the sizing machine. On this type of table, all fruit not removed before it reaches the end of the

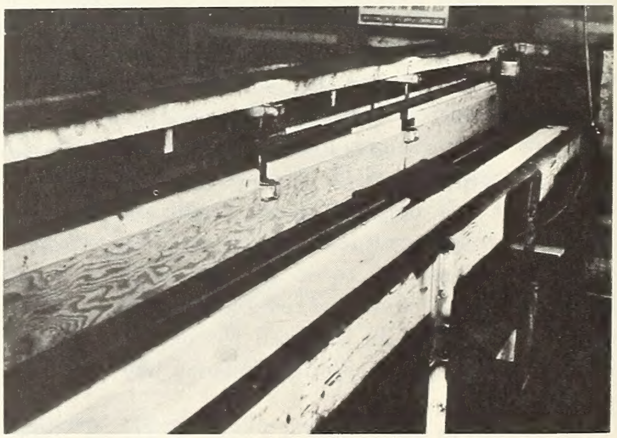

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FIGURE 1.—A belt-type sorting table.

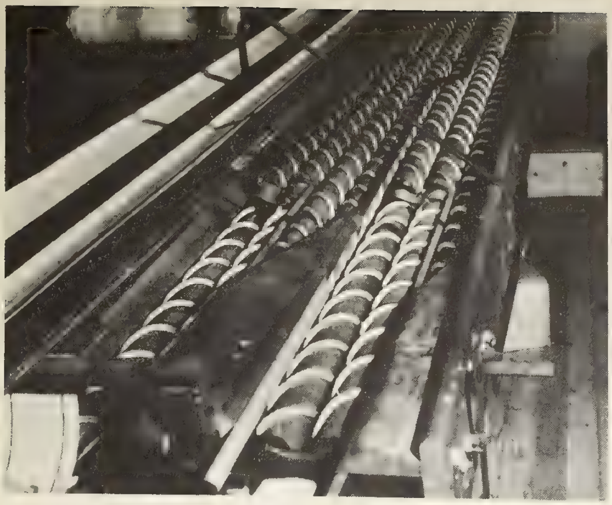

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FIGURE 2.—A spiral-roll sorting table.

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FIGURE 3.—A reverse-roll sorting table.

table is diverted by a diagonal board, or some shunting device, onto a smaller belt running in the opposite direction. This "overflow" of fruit is returned to the head of the sorting table, shunted onto the main belt, and again passed before the sorters.

Spiral-Roll Table

The spiral-roll table is more efficient than the belt table (fig. 2). More of the surface of the fruit can be visually inspected on this table than on the belt table because the fruit is turned over as it is moved forward. This table usually consists of 5 to 7 wooden rollers, approximately 2½ inches in diameter and extending horizontally the full length of the table, on either side of the center conveyor belts. A quarter-inch hard-woven rope is spirally wrapped around the rollers with approximately 3 inches between turns. The fruit is rotated by the revolving action of the rollers and is conveyed forward by the ropes, which act as a worm screw. On this table any fruit not lifted from the table by the sorters flows off the ends of the rollers onto conveyor belts leading to the sizing machine.

Reverse-Roll Table

Figure 3 shows a reverse-roll type of table, which usually consists of a metal frame with a plywood bottom. The fruit is rolled over the plywood by a series of rubber rollers spaced about 4 inches apart and extending the full width of the table. These rollers move over the table like a conveyor chain; a gear arrangement causes them to rotate backward while the fruit is rolled forward. This turns the fruit over, permitting free visual inspection of most of the surface of the fruit while it is on the table. Apples not lifted from the table move directly from the end of the table to the sizing machine.

FACTORS AFFECTING SORTING EFFICIENCY

Before World War II, apples grown in the Pacific Northwest were sorted into Extra Fancy, Fancy, C grade, and culls. Since the grading laws permitted these grades to be combined in various ways, the general practice during the war years was to combine Extra Fancy and Fancy into 1 grade called the Combination grade. In recent years, however, the apple market has resumed the use of 3 grades.

The official apple grading standards of the State of Washington specify the types of blemishes, defects, and degrees of color required in each of the three grades of Extra Fancy, Fancy, and C. However, literal reading of the grades oversimplifies the sorting operation. Actually, most of the grading elements must be determined in degrees. A blemish, for instance, may not lower the grade of the fruit unless it is of a serious degree. This makes the sorting operation difficult; such factors as color, blemishes, and shape must be judged subjectively, since no clear demarcation between grades exists. Many borderline cases arise where an apple might be graded as either C grade or Fancy, depending upon the judgment of the sorter. Some types of defects are difficult to detect without close examination of the fruit.

The grading of apples is essentially surface inspecting to evaluate the degree of defects rather than presence of defects. The sorter's main task is to determine subjectively the quality of the fruit on the basis of varying degrees of color and blemishes.

In measuring the efficiency of various sorting methods and equipment, it was necessary to isolate certain factors. These factors were broken down into 5 categories: (1) Type of sorting table, (2) quality of fruit, (3) size of fruit, (4) physical capacity of workers, and (5) management factors. Many variables doubtlessly exist that have not yet been brought to light, or are considered unimportant.

Prior to this study it was believed that number of grades sorted (2 grades versus 3 grades) greatly affected sorting efficiency. Results of the study showed that efficiency factors are similar whether workers sort 2 grades or 3, except that when sorting 3 grades, workers must lift more fruit and make more decisions. This is a sixth variable factor.

Another variable is the ease with which the apples may be inspected visually. This depends largely upon the adequacy of lighting, the color background of the table, and the visual acuteness of the sorters. In this study these factors were assumed to be constant.

Type of Sorting Table

The type of sorting table may affect the efficiency of sorting in two ways: First, by redistributing the workload to permit workers to utilize their time more fully; second, by altering motions or motion patterns to permit workers to work more efficiently. Redistribution of the workload is discussed later.

Contributions of a sorting table to the ease of inspection are dependent upon (1) regularity of space and arrangement of the apples as they are presented for inspection, and (2) the way apples are rotated on the table to facilitate visual observation by sorters. Improving one or both of these factors enables sorters to inspect more apples with the same amount of effort.

The regularity with which apples are presented for inspection differs on the three types of tables. On a belt table the apples are conveyed, randomly grouped, to sorters; part of the inspection is done by holding the apple in the hand. The belt table, with no runoff, serves only as a means of getting fruit past the sorters. On the spiral-roll table apples are alined in rows with no regular spacing of the fruit, and with parts of the surfaces of some apples obscured by other apples. On the reverse-roll table apples are alined by a series of rollers extending the width of the table. The rollers provide regular spacing between consecutive apples. However, the fruit is not presented in rows the full length of the table as on a spiral-roll table. Changing these tables to provide more regular spacing in both directions results in a more efficient sorting operation.

The second factor considered was the presentation of apples to permit free visual inspection of the apple surface. On the belt table the sorter must turn over or rotate the apples by hand. The spiral-roll table rotates the apples as they move along the table. This rotation is irregular, however, particularly when the table is used to full capacity and crowded with apples. The reverse-roll table tends to rotate the apples more freely and uniformly, making visual inspection easier.

Quality and Size of Fruit

The quality of the fruit affects the speed with which apples can be sorted. Most packinghouse operators have found that, when fruit is of poor quality, sorting is difficult unless additional sorters are hired. The only alternatives are to reduce the rate of dumping, or lower the quality of sorted fruit.

The amount of inspection required depends upon the percentage of below-grade or defective apples that must be separated from the high-grade apples. The relationship of the amount of inspection needed to the quality of the fruit, assuming that 95 percent is correctly graded, is as follows:

Percentage of low-grade fruit:	*Inspection required*[1] *(Percent)*
10	52.6
15	70.2
25	84.2
35	90.2
45	93.6
55	95.7

[1] Percentage of fruit that must be inspected to obtain 95 percent of correctly graded fruit; this is based on the following formula:

$$\text{I. R.} = \frac{[\text{number of apples in lot} - (\text{number of good apples in lot} \div 0.95)] \times 100}{\text{number of low-grade apples in lot}}$$

The nature of defects or blemishes in the fruit is another factor influencing sorting efficiency. If the surface of an apple is blemished, the severity of the aggregate area of the blemish must be ascertained. This is particularly true of such blemishes as hail marks, sunburn, and russeting. When these defects

occur infrequently in a lot of apples, sorters have little difficulty in detecting and evaluating them; they are obvious by contrast with the major portion which is not defective. Sorters are then able to use a scanning method of inspection—inspecting several apples simultaneously. However, when more than 35 percent of a lot is defective, a sorter must evaluate each apple individually.

Where the sorting table rotates the apples (spiral-roll and reverse-roll tables) the time required to inspect the surface of an apple is largely dependent on the rate of rotation. When the apples are moved along the table at a constant speed, as they are on both the spiral-roll and reverse-roll tables, rotations per minute vary directly with the size of the fruit. Thus, more time is required to inspect the surface of an apple 3½ inches in diameter than one only 2¾ inches in diameter. For example, when fruit moves over the table at a speed of 25 feet per minute, a size 80 apple, with a diameter of 3 inches, rotates once every 2.20 seconds; a size 150 apple, with a diameter of 2½ inches, rotates once every 1.73 seconds.

Since small apples take less time to rotate than large ones, it would appear that small apples would be easier to sort. This, however, is not the case, presumably because of such compensating factors as these: (1) Small apples with hard-to-see defects are likely to be difficult to inspect because they rotate too fast; (2) large apples with obvious defects can often be evaluated without rotating at all. Determining the effect these factors have on sorting efficiency was beyond the scope of this study.

Statements made by packinghouse supervisors bore out the results of sorting tests, which indicated there was no noticeable difference in speed of sorting small and large apples.

Physical Capacity of Sorters

If inspection could be done without lifting apples from the table, the number of apples that could be sorted would depend in large part upon the amount of visual inspection needed. The number of apples lifted for inspection limits the total number that can be graded. This is particularly noticeable on the no-runoff belt table, where every apple must be lifted. On tables where one or more grades are run off the end of the table, the number of apples lifted is dependent upon the quality of the fruit. On this type of table the number of apples lifted does not limit the total number of apples inspected, except when quality of the fruit is very poor. When a sorter looks only at fruit directly in front of her on the table, as most sorters do on all 3 types of tables, there is a portion of the fruit that generally she cannot see, unless she picks it up and turns it over in her hand.

Dumping Rate

In some plants sorting efficiency is influenced by managerial judgment and discretion. One important operation controlled by management is the rate at which fruit is presented for inspection (dumping rate).

The concept of the amount of work a sorter should do varies widely from plant to plant. In some plants the dumping rate is so fast that sorters have difficulty maintaining less than 10 percent under-grade fruit in the outgoing lot.[1] In other plants a given number of boxes is selected somewhat arbitrarily as an average and the dumping rate maintained as close to that average as possible.

In the apple packing industry, some plants try to maintain a high rate of production at all times. Among the reasons for doing so are the following:

(1) Packed fruit costs less to store than unpacked fruit. A packed box holds about one-third more apples than a box of loose fruit, and storage costs are based partly on the amount of cold-storage space utilized.

(2) Increased production during the harvest period enables management to take advantage of a favorable early market. Rapid sorting when there is a good demand for apples during the early stages of harvest permits a plant to ship additional fruit to market, thus augmenting the income of the growers.

(3) Most sorters are employed by the hour. Output per worker affects the cost of the packed boxes. Since the daily wage per sorter is constant, the cost per packed box is proportionally less as more boxes are packed. In many cases, output can be increased by varying the dumping rate as the quality varies, so that sorters will spend less time waiting for work.

(4) Higher production rates make possible a higher annual volume. Production rates are closely related to sorting, which is affected by many factors including the number of workers per sorting table. Plants using belt tables generally need more sorters than plants with spiral-roll or reverse-roll tables; the production rate, however, is usually lower with belt tables. Some plants use more than the usual number of sorters per table. This sometimes

[1] Standards for apples in the State of Washington permit 10 percent of fruit in any container, at time of packing, to be below the grade shown on the container.

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results in fewer apples sorted per hour, per sorter, but it does increase the daily pack-out.

Number of Grades Sorted

The number of grades sorted is another factor affecting sorting costs and efficiency. The practice in the industry, at the time of the study, was to sort the fruit into 2 grades—Combination (Extra Fancy and Fancy) and C grade. The practice at the present time is to sort 3 grades—Extra Fancy, Fancy, and C. Actually, another grade, culls, should be added to both groups, for the fruit in reality is separated into 3 and 4 grades.

The practice of packing 2 grades simplifies the handling and marketing of the fruit. Packinghouse operators recognize that the 2-grade pack is less expensive and more advantageous, if market acceptance is satisfactory.

Reasons for increased cost of sorting 3 grades rather than 2 are: (1) Greater discrimination is required of the sorters; (2) more apples must be handled by sorters; and (3) capacity of sizing equipment is limited.

Sorters must make many more decisions and carefully inspect more fruit when sorting 3 grades of apples than when sorting only 2. When changing from sorting 2 grades to sorting 3, the effect on the total number of apples inspected is similar to that of a drop in quality.

It is necessary at times to reduce the speed of the sorting line because the number of apples in 1 grade is greater than the capacity of 1 part of the sizing line.

COMPARATIVE EFFICIENCY OF THREE TYPES OF SORTING TABLES

Data obtained for the sorting operation reflected the combined influence of the factors discussed in the previous sections—type of sorting table, quality of fruit, size of fruit, physical capacity of workers, and management factors. To emphasize the efficiencies of the different types of equipment, effects of other factors were ignored or held constant.

Quality of the fruit varies widely, but it is easy to measure. The data were classified as follows: All lots containing less than 30 percent of Fancy, C grade, and culls were classified as good quality; lots containing 30 percent or more were classified as poor quality.

When Sorting Good Fruit

When sorting fruit of good quality, the relative efficiency of various types of equipment was apparent. With good fruit the time required for visual inspection was the major factor that limited output.

The belt table was found to be the least efficient of the three tables (table 1), because all apples must be lifted from this type of table. No appreciable difference in efficiency was found between the spiral-roll and reverse-roll tables, but the data did not entirely eliminate quality as a factor. Fruit sorted on the reverse-roll table contained a larger percentage of defective fruit; this indicates that the reverse-roll table is slightly more efficient than the spiral-roll table when sorting good fruit.

TABLE 1.—*Number of apples of good quality inspected per sorter on 3 types of sorting tables in 6 apple packing plants* [1]

Equipment and plant number	Quality of fruit		Number of sorters	Apples inspected per sorter per hour
	C grade	Culls		
Belt table:	*Percent*	*Percent*		
Plant 1	20	6	10	3,000
Spiral table:				
Plant 2	14	7	11	3,514
Plant 3	10	4	10	4,092
Plant 4	11	3	8	3,644
Reverse-roll table:				
Plant 5	20	9	8	3,621
Plant 6	18	5	8	3,434
Plant 6	19	6	6	4,053

[1] Lots containing less than 30 percent of C grade and cull apples.

When Sorting Poor Fruit

Efficiency of the belt table approached that of the spiral-roll and reverse-roll tables when fruit of poor quality was sorted. On the belt table, all apples in each grade must be lifted from the table as they are inspected; thus, only one sorter inspects each apple. In contrast, on a spiral-roll or reverse-roll table, where only part of the apples are lifted from the table, each apple left on the table generally is inspected by more than one sorter. Because each apple must be inspected individually when sorting poor fruit, the duplication of inspection on the spiral-roll and reverse-roll tables considerably reduces the total number of apples that can be inspected. This duplication, as the quality of the fruit decreases,

reaches the point of reducing the advantage of a runoff table. The duplication that occurs when good fruit is sorted is not as great, because several apples are inspected simultaneously.

The reverse-roll table was the most efficient for sorting fruit of poor quality (table 2). Although duplication of sorting is characteristic of this type of table, this disadvantage is offset by the greater ease of inspection.

TABLE 2.—*Number of apples of poor quality inspected per sorter on 3 types of sorting tables in 3 apple packing plants* [1]

Equipment and plant number	Quality of fruit		Number of sorters	Apples inspected per sorter per hour
	C grade	Culls		
Belt table:	*Percent*	*Percent*		
Plant 7	36	8	10	2,240
Plant 7	39	7	10	2,450
Spiral table:				
Plant 8	48	11	8	2,487
Reverse-roll table:				
Plant 6	27	19	8	3,080
Plant 6	48	4	8	2,930
Plant 6	30	27	8	2,769

[1] Lots containing more than 30 percent of C grade and cull apples.

Sorting Rates for Fruit of Different Qualities

Figure 4 shows the estimated number of apples inspected per sorter, per hour, at different levels of quality (percentages of C grade and culls), on the 3 tables. The low efficiency of the belt table is probably due to the fact that the physical labor involved in lifting all apples from the table limits the total number that can be sorted. That is, only so many apples can be lifted in a given time.

On the reverse-roll table, the rolls serve to separate the apples in rows approximately 4 inches apart. This permits the apples to roll freely and makes visual inspection of the surface easier.

On the spiral-roll table the apples tend to group themselves together; at times, when volume is heavy, they skid on the rolls with little rotation or forward movement. When the spiral-roll table is not crowded, apples tend to rotate freely and pass before the sorters with regular spacing in rows the length of the table, so that ease of visual inspection is about the same as on the reverse-roll table.

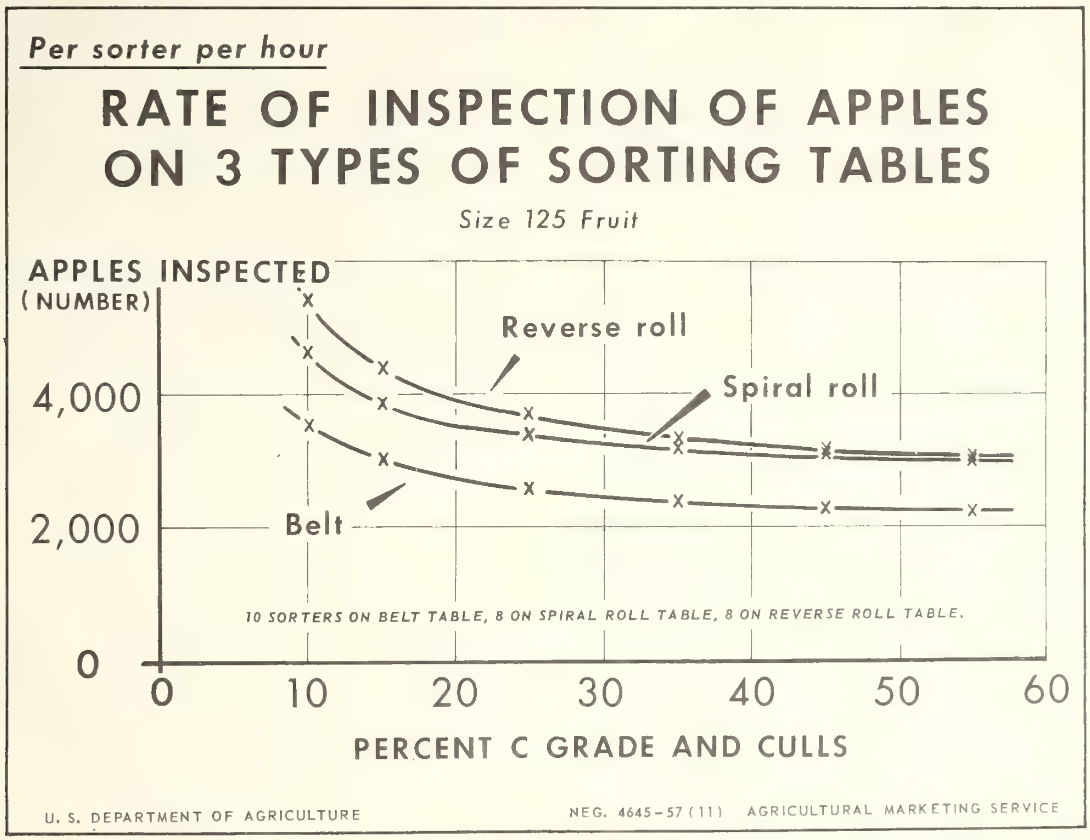

FIGURE 4

Because the reverse-roll table was the most efficient of the 3 tables tested, additional studies of this table were undertaken. The objectives of these studies were (1) to redistribute the workload so that some workers were not overworked while others were relatively idle, and (2) to simplify the operation by changing the pattern of motions, the need for making motions, or the extent of motions.

In developing improvements of methods and equipment, the major goal was to increase the capacity of workers. Studies on improvements of the reverse-roll table were made in a plant equipped with 2 such tables. Changes were made on one table while the other table remained unchanged. The 3 changes were as follows: (1) The surface of the table was divided into lanes, (2) variable speed of translation (speed at which the rolls move over the table) was made possible, and (3) a cull disposal chute was installed beside each sorter.

Division of Sorting Surface Into Lanes

The typical reverse-roll table, approximately 48 inches wide, is divided into 2 or 3 sections running the length of the table. The work area on either side of the table is approximately 24 inches wide, and extends from the edge to the center of the table. Some apples, left on the table after they pass the first 2 sorters, are inspected a second and sometimes a third time by other sorters on the same side of the table. This is needless duplication of work. Another shortcoming is the inability of management to place individual responsibility on sorters for the proper grading of fruit that runs off the end of the table.

The work surface of 1 table was divided into 6 lanes, 3 on either side of the small runoff belts, running the length of the table (fig. 5). This was accomplished by attaching links between rolls at approximately 8-inch intervals across the width of the table. The links were about 1 inch above the table surface and flush with the tops of the rollers; the apples could not roll from 1 lane to another. After the lanes were installed, each sorter was assigned a lane and instructed to sort only the apples in that lane. Thus all of the apples were inspected only once.

Efficiency of sorters increased by 10 to 46 percent after lanes were installed (table 3). Furthermore, their efficiency increased in sorting apples of every quality, but especially when less than 35 percent of the fruit was of low grade.

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FIGURE 5.—Reverse roll sorting table divided into lanes. Note cull disposal chutes at each work station.

(1) *Duplication of work was eliminated.*—Because each sorter was assigned only 1 lane, each apple was inspected only once. The sorters were able to inspect more apples in a given time with apparently no more effort than was required on the original table. Since no other changes were made, the increased efficiency was attributed to the elimination of duplication.

(2) *Sorters developed feeling of responsibility.*—The use of lanes gave sorters a feeling of responsibility for the flow of fruit allotted them. This change in attitude of sorters was definitely noticeable. They

TABLE 3.—*Number of apples of specified qualities and size sorted on a reverse-roll sorting table before and after individual work lanes were installed*

Percentage of low-grade fruit	Apples inspected per sorter per hour [1]		Increase
	Without lanes	With lanes	
			Percent
10	5,346	7,869	46
15	4,410	5,994	36
25	3,624	4,500	24
35	3,286	3,858	17
45	3,098	3,500	13
55	2,979	3,274	10

[1] Size 125 apples (2¾ inches in diameter).

knew how much work was expected of them. On the typical reverse-roll table some ill feeling among sorters was noted. Because of the imbalance of the workload, 1 or 2 of them did not do a fair share of the work. When lanes evenly divided the workload among sorters, this difficulty was removed. The feeling of responsibility seemed to create a desire to maintain a high rate of production. This psychological factor seems to be a significant advantage in dividing a sorting table into lanes.

(3) *Work was equalized among sorters.*—Under the present system of sorting on all types of tables, the amount of work performed by individual sorters varies widely. Most of the apples removed from the table are lifted by the first two sorters on either side of the table. Usually these sorters try to remove as many of the low-grade and cull apples as possible. Consequently the remaining sorters are idle a good part of the time.

The unequal workload was eliminated, after lanes were installed. The flow of fruit past sorters was equalized by dividing the table surface into six lanes. Approximately the same number of apples was presented to each sorter, and about the same number of apples was lifted by each sorter.

(4) *Work of each sorter can be checked.*—When lanes were used, each sorter was responsible for grading apples in only 1 lane. Since apples in 1 lane did not mix with apples in the other lanes, supervisors were able to evaluate the skill of individual sorters. On the standard table, it was impossible to affix responsibility on individual sorters for the sorting errors since there was no way of keeping separate the apples inspected by each sorter.

(5) *Better sorting techniques were possible.*—Sorters adopted more efficient sorting variations when working on the table equipped with lanes. On this table, the sorters did most of the inspection while the apples remained on the table. On the other table, sorters picked up more than half of the apples in order to inspect them. When lanes were used the percentage of apples inspected while on the table increased from 44 to 70 percent.

Sorters necessarily developed more efficient work habits. While a sorter is hand-inspecting an apple, she may fail to see defective apples that pass by on the table. Without the lanes sorters were not greatly concerned about the defective apples they missed. However, when a sorter was responsible for inspecting all the apples in one lane she had to adopt more efficient work habits.

When working on the standard reverse-roll table, a sorter frequently picks up an apple from the table and, after a closer inspection in the hand, returns it to the table. This is wasted motion. A comparison of these types of mistakes, on the tables with and without lanes, provides still another reason for the use of lanes. On the standard reverse-roll table, 16 percent of all apples lifted were put back on the table. This compares with only 5 percent for the lane-equipped table (table 4). By confining inspection to the small area enclosed by 1 lane, a sorter made more positive decisions after only 1 inspection.

Most of the sorters preferred working on the lane-equipped table. They stated that the lanes made the work much easier and assured each sorter of doing only her fair share of the work. Another remark frequently heard was that one sorter could not be blamed for another sorter's mistakes. A decided improvement was noted in the morale of sorters using the table equipped with lanes.

Figure 6 shows the "before" and "after" workload distribution among sorters on the improved and the standard reverse-roll tables.

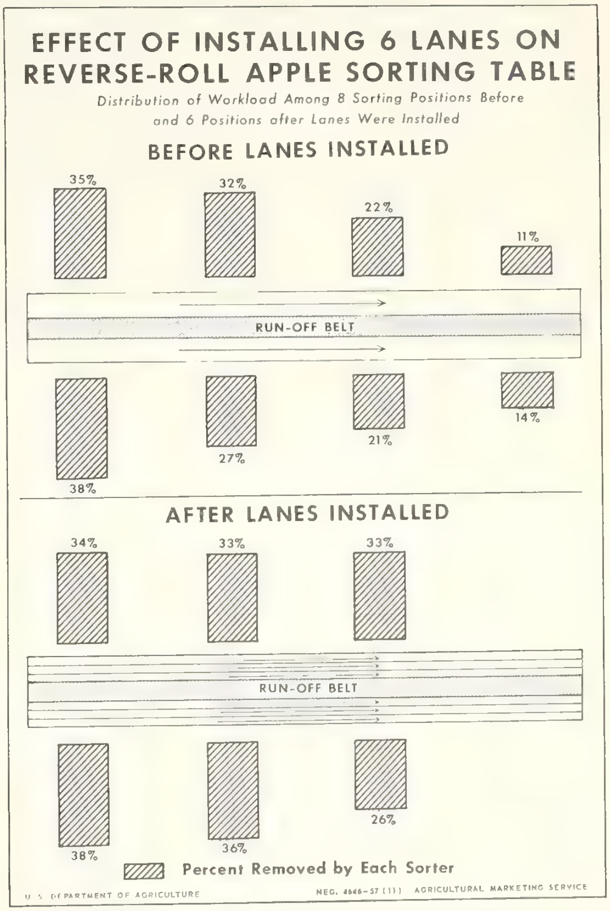

FIGURE 6

TABLE 4.—*Percentages of apples picked up by sorters and returned to table before and after individual work lanes were installed on the reverse-roll table*

Sorter	Percentage of apples picked up and returned to table	
	Without lanes	With lanes
A	7	2
B	20	9
C	29	14
D	12	4
E	11	3
Average	16	5

Varying the Translation Speed

The improved reverse-roll sorting table was equipped with a variable-speed drive. With this drive the forward speed of the rolls could be varied between 10 and 30 feet per minute. In plants surveyed, the tables were generally operated at about 18 feet per minute. At this speed, the apples tended to group closely together between the rolls. When the table was covered with fruit, the sorters appeared to be working to capacity. Only a limited number of apples could be inspected because of the slow speed.

The speed of the rolls determined the number of times per minute the apples on the table rotated. When the speed of the rolls was increased, the number of rotations per minute also increased. By changing the speed of the table an attempt was made to derive a specific speed and rotation at which the sorters worked most efficiently.

In a series of trials spread over several weeks, the table was set at different speeds ranging from 15 to 30 feet per minute. The table was operated at each speed setting for at least 1 full day. When the speed was increased, most sorters said at first that the apples moved too fast. However, when they became accustomed to the increased speed within an hour or two, most of them expressed a preference for the higher speed. When the speed was greater than 25 feet per minute, many sorters could not inspect the apples thoroughly. Consequently more than 5 percent of below-grade apples were missed. The speed preferred by most sorters was approximately 25 feet per minute. The table was operated at this speed for several days, and then reduced to around 20 feet per minute. The sorters then complained that rotation was too slow.

The increased table speed had a decided effect on sorting techniques. At low speed, workers sorted the fruit directly in front of them. At faster speeds, sorters tended to face in the direction of the oncoming fruit (fig. 7). Thus the fruit was inspected at a point up the table rather than directly in front of the sorter. This is desirable, because the sorter is able to see more of an apple's surface. When a sorter looks only at the fruit directly in front of her, she cannot generally see the whole surface unless she turns it over by hand.

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FIGURE 7.—Slightly higher speed of translation caused sorters to face toward the flow of the oncoming fruit.

Cull Disposal Chutes

The cull disposal conveyor belt on most sorting tables is located over the center of the sorting table, usually 15 to 18 inches above the table surface. The average distance from all parts of the table surface to the cull disposal belt is about 20 inches. (The distance from the edge of the table to the cull belt is approximately 25 inches.)

To lessen the time required to dispose of culls, and to reduce fatigue of sorters, a disposal chute was installed beside each sorter (see fig. 5), toward the direction from which the fruit flowed. This also induced sorters to face that direction. The culls placed in the chutes dropped onto a conveyor belt running beneath the table.

Placing cull chutes beside the sorters reduced the distance culls were moved by hand, and reduced the time required to dispose of culls by about one-third. This is an important element in the sorting operation, since cull apples are usually not randomly

distributed throughout the fruit but frequently appear in groups. Because it is sometimes necessary to remove a large number of culls quickly, the time saved by the use of cull chutes represents a significant improvement. Time checks made on a cull belt located in the center of the table and on chutes located beside the sorters showed that it took 2.5 minutes to dispose of 100 culls via the belt and only 1.6 minutes via the chutes, a time saving of 36 percent.

With cull disposal chutes, sorters used both hands to remove apples from the table. Sorters removed culls with the hand nearest the cull chute, and transferred other apples to the proper conveyor belt with the other hand. When a large number of low-grade apples had to be removed, the use of two hands enabled sorters to remove the apples with a minimum of interference with visual inspection of the apples still on the table.

Additional Sorters at Head of Table

The improved reverse-roll table was built to accommodate only 6 sorters, 3 on either side of the table. In most plants using 3-section sizers, 6 workers are able to sort enough top-quality fruit to maintain most other packing room operations at or near optimum levels. However, when poor-quality fruit is sorted, the total volume sorted by 6 workers falls below the requirements of the other packing room operations. In order to maintain production rates, when sorting poor-quality fruit, it is necessary to employ 2 to 4 additional sorters.

With the improved reverse-roll table the general practice of stationing additional sorters at the end of the table nearest the sizing line increased production only slightly. The 2 additional sorters stationed at that end of the table removed less than 15 percent of the total number of apples lifted from the table. Furthermore, the additional sorters returned to the table 30 to 50 percent of the apples they picked up. Since the additional sorters spent most of their time inspecting apples already inspected by the other sorters, only a slight increase in production was noted.

When 2 additional sorters were stationed at the beginning of the table—before the flow of fruit reached the first regular sorters on either side of the table—production increased. These 2 sorters were instructed to scan the entire flow of fruit and pick out the obviously defective apples; final inspection was made by the regular sorters sorting in lanes. Removal of the below-grade apples by the added sorters improved the quality of the fruit flowing past the regular sorters. A proportionately greater number of apples was inspected per sorter, as the quality of the fruit improved.

Controlled Dumping Rate

Variations in size and quality make it impossible at times to supply enough fruit to maintain sorting at maximum efficiency. In many packing plants little consideration is given to size and quality of fruit when setting the dumping rate; hence sorters sometimes work above a normal rate and at other times below normal. Generally, sorters work below maximum efficiency because management uses no measure of the amount of work sorters can do. The sorters establish their own workpace.

An aid in achieving a high rate of production is a chart showing the number of boxes of apples that could be dumped per hour for various levels of quality and size. Table 5 shows how a dumping-rate chart can be drawn up. The upper part of the table shows the method used to accumulate the necessary data.[2] As the number of lots recorded in this table is not sufficient to develop a chart for all sizes, the method is illustrated for size 125. Readings from the curve shown in figure 8 can then be set up in tabular form like that shown in the lower half of table 5. Figure 8 is intended to serve only as a guide. It would be desirable for plant operators using other types of sorting tables to develop similar charts because of the variations in conditions that occur from plant to plant. To prepare such charts, plant operators would have to maintain detailed records for several weeks of the number of boxes dumped per hour and the average size and quality of the fruit sorted.

To fully utilize a dumping-rate control chart, the sorting supervisor should maintain a close check on the size and quality of the fruit being sorted so that the dumping rate can be maintained at the proper level. Before a lot of fruit is sorted the supervisor should examine it to estimate the average size and quality of the apples, and he should set the dumping rate accordingly. Also, while fruit is being sorted, he can estimate the size and quality from the distribution of the apples falling into the packing tubs. Quality and size of fruit should be checked occasionally while the lot is being sorted in order to detect variations that might occur.

The total labor cost of hourly workers on a typical

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[2] Derived from data obtained in making this study.

TABLE 5.—*Sample form for recording daily performance of sorting table and expected dumping rates in unpacked boxes, per hour, for apples of various sizes and qualities on a spiral-roll sorting table using 8 sorters*

Lot number	Apple size [1]	Percentage of low-grade fruit	Hourly dumping rate	Lot number	Apple size [1]	Percentage of low-grade fruit	Hourly dumping rate
			Boxes				*Boxes*
1	138	27	255	11	125	17	315
2	150	15	300	12	125	25	290
3	125	20	310	13	138	38	250
4	125	35	275	14	125	28	250
5	163	45	225	15	138	22	270
6	125	48	265	16	125	21	280
7	88	30	330	17	150	25	250
8	100	26	320	18	125	45	250
9	125	40	270	19	138	40	250
10	138	30	265				

Percentage of low-grade fruit	Hourly dumping rate for apples of size—				
	100	113	125	138	150
			Boxes		
15			340		
20			305		
25			290		
30			280		
35			270		
40			265		
45			260		

[1] Size shows number of apples required to fill a packed box (standard Northwest apple box, outside dimensions 12 by 11 by 19½ inches). Size 125 apples are 2¾ inches in diameter.

packing line is about $200 a day, or about $1,000 a week.[3] Labor cost for apple packers is excluded from these totals; most packers are paid on a per-unit-of-output basis in the Pacific Northwest. If, by using a dumping-rate chart, a single packing-line plant could increase its dumping rate by 5 to 10 percent (this amount could be expected), a saving of $50 to $100 per week could be realized. For a 3-month packing season, $650 to $1,300 might be saved.

ADAPTING IMPROVEMENTS TO OTHER SORTING TABLES

Sorting efficiency on the reverse-roll table was increased substantially by the addition of individual lanes. This new principle can be applied to the belt and spiral-roll tables as well. However, the narrow work surface of some tables will limit the number of lanes. With narrow tables the full value of lanes may not be realized, because it would be impossible to assign only 1 sorter to a lane. On these tables, 2 sorters may be assigned to a lane, provided the lane carries more fruit than 1 sorter can inspect and grade. Under this system there would be some duplication of work; the second sorter would inspect some apples which the first sorter had already checked. The duplication would not be as great as under the current system of sorting, however, where the same apple may be inspected by 3 or more workers.

[3] Assuming 10 sorters, 1 stamper, 1 labeler, 1 lidder, 1 packing supplyman, 1 box supplyman, 1 cull man, 1 supervisor, 2 supplying unpacked fruit, 1 segregator, and 2 placing packed fruit in storage.

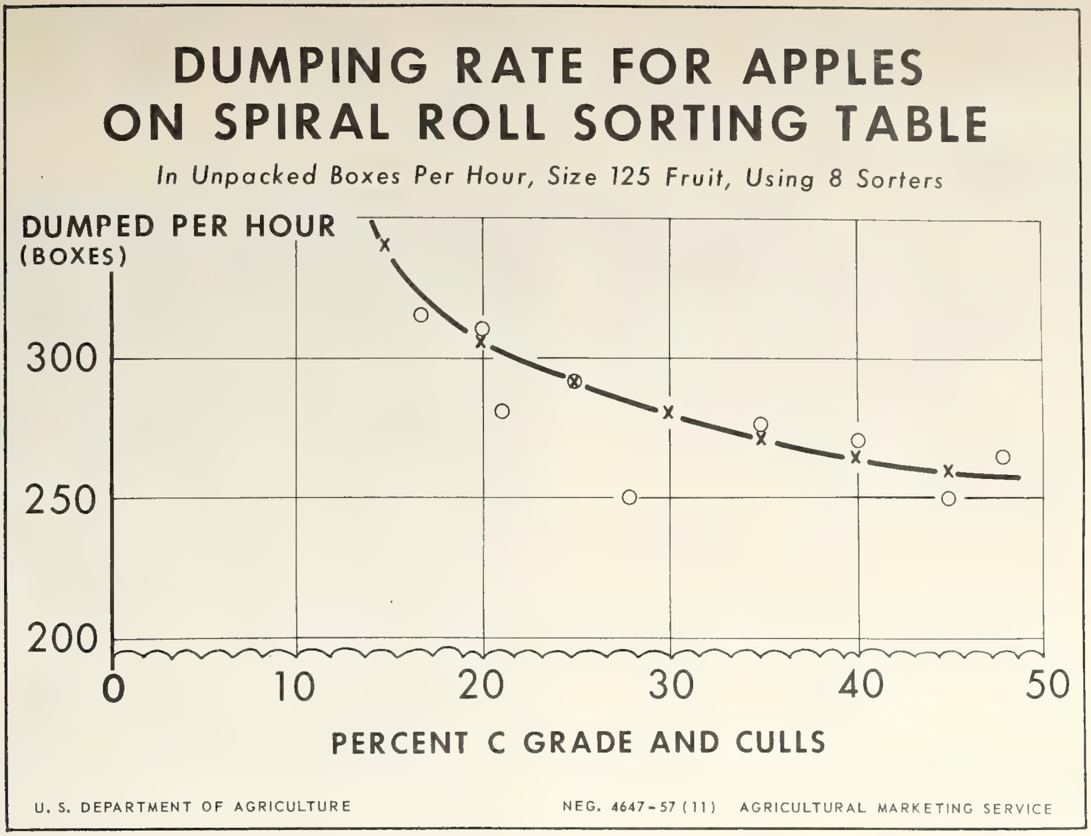

FIGURE 8

Most existing belt tables are the return flow type. They require that all apples be lifted from the table. There would be no advantage in installing lanes on this type of table unless one grade of fruit was left on the table and conveyed directly to the sizing line. Belt tables could easily be divided into lanes; however, the amount of savings would be limited because most belt tables are too narrow to accommodate more than 2 lanes on each side.

Lanes could be provided on the spiral and belt tables by using small-diameter metal rods or heavy wire, as illustrated in figure 9. The rods could be suspended about ¼ inch above the table surface. For lanes 4 inches or more in width, the rods could be attached on a belt table as shown in figure 10.

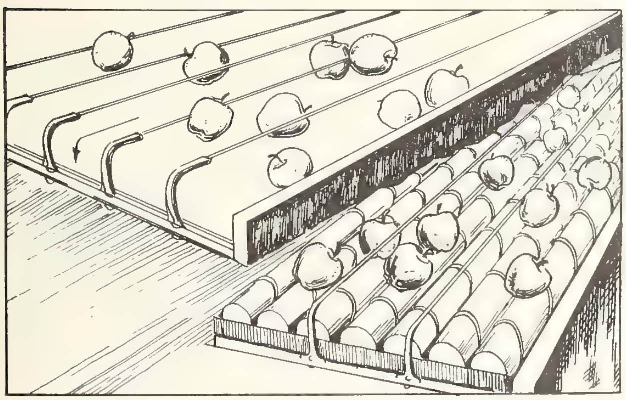

FIGURE 9.—Lanes may be made on a belt or spiral-roll table by extending rods down the length of the table.

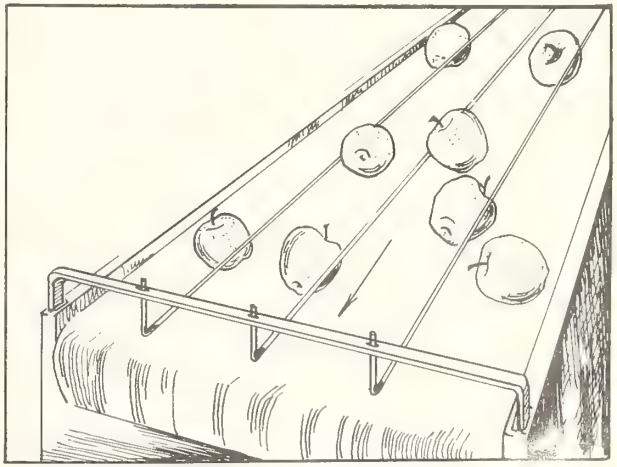

FIGURE 10.—If lanes are over 4 inches wide, rods could be attached to a brace at each end of the table.

Apples normally move down the natural valleys of the spiral-roll table. The benefits of lane sorting can be obtained by assigning workers to sort 1 or 2 of these valleys.

NEW FLOAT-ROLL SORTING TABLE

Development of New Table

Studies of the reverse-roll sorting table indicated that sorting efficiency could be increased by increasing the rotation speed beyond that possible on the reverse-roll table. On the reverse-roll table the number of times that an apple rotates in a given distance cannot be changed because the bottom of the sorting table remains stationary. The fruit is merely rolled across the table.

Following the research on the reverse-roll table, plans were developed for a new sorting table which would allow the rotation of the fruit to be altered independently of the translation speed. With controlled rotation, the best combination of forward motion and rotation for fruit of different qualities could be determined. Several new types of table surfaces were designed to utilize the 2 improvements developed by this research—lanes on tables, and variable speed of translation and rotation of fruit. Small mockups were made in order to test the action of the surfaces on the apples. The plan adopted, after considering the various alternatives, is shown in figure 11.

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FIGURE 11.—A small prototype of the float-roll sorting table.

From experience gained with the improved reverse-roll table, a small working model (prototype) of the new table was built. The surface of the table consisted of small rubber-covered rolls extending across the table. The rolls were spaced so that the fruit was carried, or "floated", on top of the rolls. The forward motion could be controlled by varying the speed at which the rolls moved down the table; the rotating speed of the fruit was controlled by varying the rate at which the rolls rotated.

The prototype was used to test several innovations in fruit sorting, including more efficient spacing of the rolls. When the centers of the rolls were 2 inches apart, the apples rotated freely, rode in full view on the table, and had a definite tendency to space themselves evenly on the rolls.

The prototype was also used to test several widths of lanes, ranging from 2½ inches to 4 inches. In the 2½-inch lane the apples moved down the table satisfactorily, but the limited space tended to keep the stem and calyx ends of the apples in a horizontal position. In a 4-inch lane, the apples did not separate as much as desired. In a 3½-inch lane, the apples rolled freely and spaced themselves at desirable distances; this width permitted the use of 6 sorting lanes on a commercial-size table without extending beyond the efficient reach of the sorters. No significant bruising of fruit was detected in the 3½-inch lane.

Some sorting tables with these advantages have been made by commercial manufacturers and will probably come into use.

Construction and Testing of Commercial Model

A commercial-type float-roll table was constructed on the pattern of the prototype (fig. 12). This table was approximately 12 inches wider than any commercial table in use. In the center of the table 2 lanes were provided to carry off 1 grade of sorted fruit. These lanes, being beyond the efficient reach of the sorters, were not used to carry unsorted fruit.

Two alternative methods for dividing the table

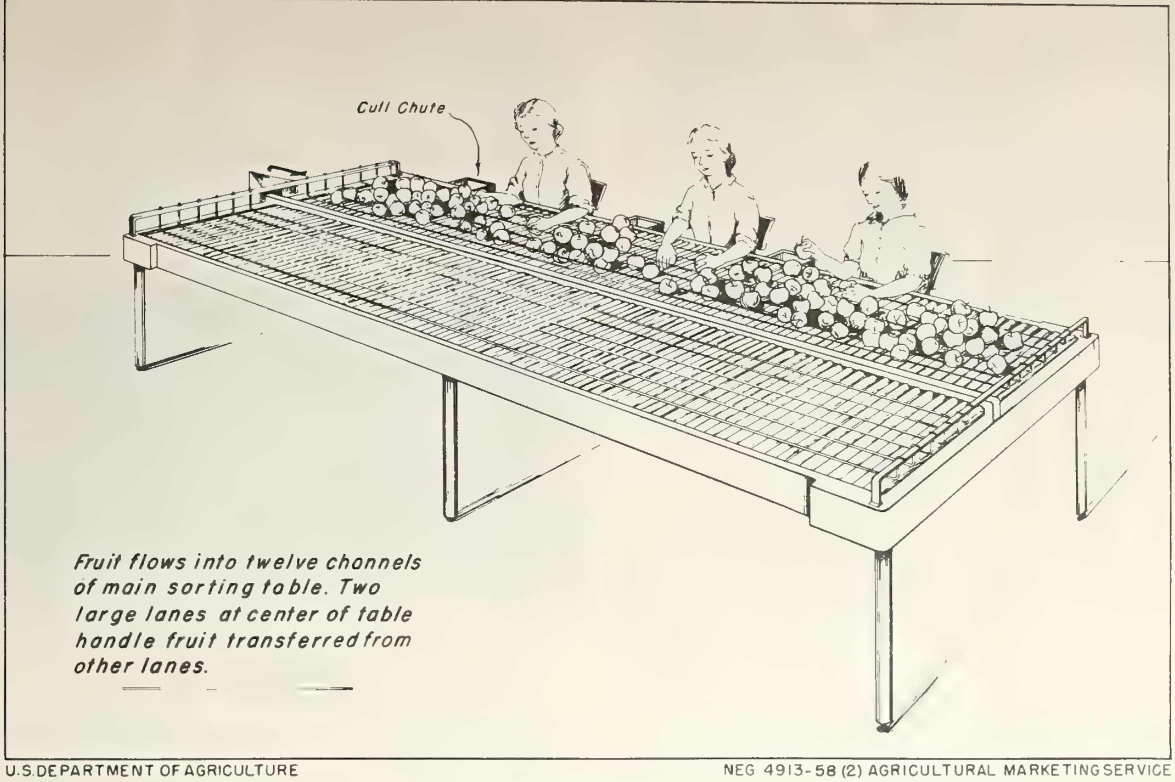

Figure 12.—Sketch of float-roll sorting table.

surface into lanes were tested (fig. 13). On one side of the table rubber washers were used to provide 6 lanes, and on the other side a series of small metal rods extending the length of the table also provided 6 lanes.

The new float-roll table was about 17 percent more efficient than the improved reverse-roll table, which in turn averaged 24 percent more efficient than the standard reverse-roll table. Table 6 shows the

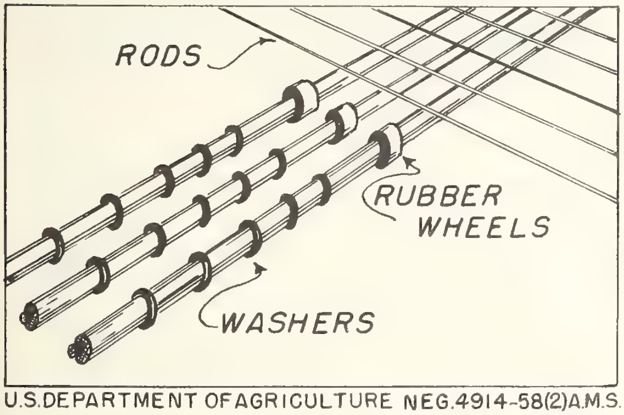

Figure 13.—Lanes may be made on the float-roll table by using rods or rubber washers.

Table 6.—*Number of size 125 apples of specified quality sorted per sorter, per hour, on float-roll and improved reverse-roll tables* [1]

Percentage of low-grade fruit	Apples inspected per sorter per hour		Difference
	On improved reverse-roll table	On float-roll table	
			Percent
10	7,869	9,500	20.7
15	5,994	7,164	19.5
20	5,064	6,000	18.5
25	4,500	5,302	17.8
30	4,124	4,834	17.2
35	3,858	4,500	16.6
40	3,656	4,250	16.2
45	3,500	4,056	15.9
50	3,376	3,900	15.5
55	3,274	3,774	15.3
Average	4,522	5,328	17.3

[1] Size 125 apples are 2¾ inches in diameter.

number of apples of specified qualities sorted on both the float-roll and the improved reverse-roll tables; the relative increase in efficiency was about the same at all levels of quality. After preliminary testing, the float-roll table was installed in a commercial packing line.

While setting up the table for operation, the two variable-speed drives controlling rotation and translation were calibrated to obtain approximate settings for various combinations of forward motion and rotation. The gearing of the table was adjusted so that the forward speed could be varied between 15 and 40 feet per minute; the rotational speed of a size 125 apple could be varied between 0 and 70 revolutions per minute.

Advantages of New Table

It is not known which factors contributed most to the increased efficiency of the float-roll sorting table. Disregarding order of importance, some of the factors are:

(1) Single lanes for sorters enabled them to establish a definite rhythm in their work.

(2) The smooth rotation of the fruit aided visual inspection of the complete surface.

(3) Because the fruit rested on top of the rolls, it could be seen more clearly and completely.

(4) The background of the rolls, coated with white paint, reduced eyestrain.

(5) The apples were not crowded on the table.

(6) The speed of forward motion could be varied.

One main reason for the increased efficiency of the float-roll table was the presentation of apples in a single row. This resulted in a steady flow of fruit past each sorter in a manner which enabled her to use rhythm in her sorting motions; apparently no more effort was required of the sorters on this table than on the improved reverse-roll table. Rhythmic motions enabled a sorter to distribute her time among all the apples in her assigned lane, so that few of the apples in the lane passed by uninspected.

On the float-roll table the apples were carried on top of the rolls, rather than in between them, so that the fruit rotated smoothly and continuously. This constant rotation enabled sorters to see the surface of each apple clearly and to notice defects readily. On a reverse-roll table the apples are pushed across a stationary surface, and they rotate irregularly and with a slight jerking motion.

The importance of visual inspection of the apples was emphasized by sorters' comments. About 20 different sorters worked on the float-roll table during the test period; they stated that defects on apples were easier to see, and eyestrain was considerably reduced. The action of the rolls tended to spread the apples, with the result that fruit was presented to sorters at regular intervals (fig. 14). Many of the sorters worked alternately on the float-roll table and on a reverse-roll table. Consequently, they had a valid basis for comparing the two tables.

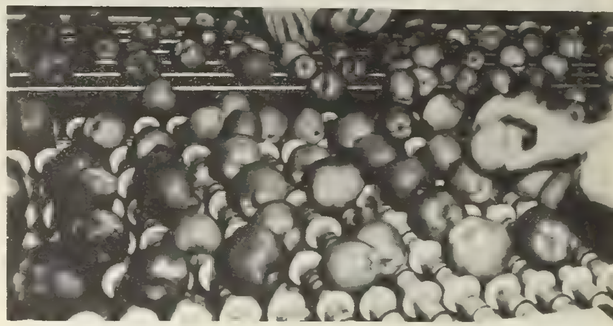

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FIGURE 14.—Apples are carried on top of the rollers, making visual inspection easier.

Before the float-roll table was installed in a commercial packing line, a light-colored paint was applied to both the rolls and the background board under the rolls. After working on the table for a short time, the sorters expressed satisfaction with the surface. They stated that inspection was easier because of the contrast in color between the apples and the sorting surface.

When poor fruit is sorted on a belt, spiral, or reverse-roll table, relatively few apples are on the table. When good fruit is sorted the apples are close together on the table; this crowding restricts rotation of the fruit. This shortcoming is eliminated on the float-roll table by changing the forward speed to correspond to the number of apples being sorted. If desired, a greater volume of fruit can be sorted by simultaneously increasing the dumping rate and the forward speed, to convey apples faster while maintaining the spacing between them. The higher forward speed is possible because the rotation of the fruit can be adjusted to a rate at which the sorters can clearly see the defects on the apples. On the other types of tables, if the speed of the table is increased, rotation of the fruit is also increased.

Variable Speeds of Translation and Rotation

The float-roll table permits a greater volume of fruit to be sorted in a day, especially when sorting good fruit. The two factors largely responsible for

this advantage are (1) the variable translating speed of the table, and (2) the extra width of the table.[4]

Variable speeds give the float-roll type of sorting table a decided advantage over other types of sorting equipment. By increasing the forward speed, more fruit can be inspected in a given time, thereby taking advantage of the fact that lots of better quality are easier to sort. In the tests the float-roll table was run at about 40 feet per minute. (Sorters were unable to sort fruit adequately on a reverse-roll table when the translating speed exceeded 28 feet per minute.) Sorters are frequently unable to inspect the best lots of fruit as fast as possible because the sorting table (belt, spiral, or reverse roll) cannot carry the volume. Faster packing of unusually good fruit is difficult in some plants because of the limited capacity of the sizing line or an insufficient number of packers. Table 7 shows the capacity of the float-roll table, when using 8 sorters, to be about 56 percent greater than the spiral-roll table and almost 18 percent greater than the improved reverse-roll table.

TABLE 7.—*Number of boxes of apples dumped, inspected, and packed, per sorter, per hour, on specified types of sorting tables.*[1]

Equipment	Apples inspected per sorter per hour [2]	Boxes of apples dumped per hour [3]	Boxes of apples packed per hour [4]
Spiral-roll	3, 397	289	206
Reverse-roll	3, 624	309	220
Improved reverse-roll	4, 500	384	274
Float-roll	5, 302	452	322

[1] Assumed average apple size 125, (2¾ inches in diameter), with 25 percent C grade and culls. Standard Northwest apple box, outside dimensions 12 by 11 by 19½ inches.

[2] Eight sorters per table.

[3] Factors considered in deriving these figures were: (a) Apples inspected per hour; (b) number of sorters; and (c) average number of apples in unpacked boxes.

[4] Assumed to be 75 percent of boxes dumped per hour less 5 percent culls.

With a 6-section weight-type sizer, the total capacity of the float-roll table could not be used to sort lots of above-average quality. The volume inspected would be too great for the sizing equipment. Table 8 shows the capacity of the commonly used 6-section weight-type sizer and the capacity of the float-roll sorting table, using 8 sorters, for fruit of various sizes and qualities. For size 125 apples, when 10 percent of the fruit is of low grade, the capacity of the float-roll table would exceed the capacity of the sizer by about 174 boxes per hour.

By test, the effect of varying the rate of rotation of the apples at different translating speeds was determined. Since the float-roll table was equipped with 2 variable-speed motors, the rotations per foot

[4] The float-roll table can be made with 4, 5, or 6 lanes on either side of the table, depending on such things as the size of the washer used and the number of sections in the sizing line

TABLE 8.—*Number of packed boxes of apples inspected by 8 sorters on a float-roll sorting table, and capacity of a 6-section weight-type sizer*

Number of apples per box [1]	Percentage of low-grade apples	Apples inspected per sorter per hour	Per hour capacity (packed boxes)		Excess sorting capacity over sizing capacity
			8 sorters	6-section sizer [2]	
			Boxes	*Boxes*	*Boxes*
88	10	9, 500	820	513	307
	15	7, 164	619	541	78
	25	5, 302	458	487	....
	35	4, 500	389	557	....
	45	4, 056	350	....	....
100	10	9, 500	722	471	251
	15	7, 164	544	498	46
	25	5, 302	403	448	....
	35	4, 500	342	512	....
	45	4, 056	308	....	....
113	10	9, 500	639	432	207
	15	7, 164	482	456	26
	25	5, 302	356	410	....
	35	4, 500	303	470	....
	45	4, 056	273	....	....
125	10	9, 500	578	404	174
	15	7, 164	436	427	9
	25	5, 302	322	385	....
	35	4, 500	274	440	....
	45	4, 056	247	....	....
138	10	9, 500	523	370	153
	15	7, 164	394	391	3
	25	5, 302	292	352	....
	35	4, 500	248	402	....
	45	4, 056	223	....	....
150	10	9, 500	481	341	140
	15	7, 164	363	359	4
	25	5, 302	269	324	....
	35	4, 500	228	370	....
	45	4, 056	206	....	....

[1] Standard Northwest apple box, outside dimensions 12 by 11 by 19½ inches.

[2] The quantity of fruit that can be sized on a 6-section weight-type sizer varies with the distribution of the grades within each lot of fruit. The quantity that can be sized is largest when about 16⅔ percent of the apples being sized go to each section, or 33⅓ percent go to each double section. The quantity that can be sized declines if the proportion of 1 grade increases.

of forward movement could be varied between zero and 4, at a forward speed of 20 feet per minute. At 35 feet per minute, the rotations per foot ranged from zero to 2½.

Tests of forward motion and rotation were made on the float-roll sorting table to duplicate those made on the improved reverse-roll table. The float-roll table was operated at a forward speed of 25 feet per minute and a rotation speed equivalent to 1.4 rotations per foot for size 125 apples. The forward speed was then increased to 35 feet per minute with the rotation speed held constant at 1.4 rotations per foot. The percentage of below-grade fruit going off the end of the table was about the same at all speeds.

When the rotation of the apples on the float-roll table is controlled, faster forward speeds are possible without reducing sorting efficiency. To determine the effect rotation alone had on sorting efficiency, studies were made holding the forward speed constant and varying the rotation speed. No clear relationship existed between the rate of rotation and the average quality of the outgoing fruit within the practical ranges of the rotation speeds studied (table 9). Although a satisfactory sorting job was accomplished for all combinations of forward speeds and rotations observed, some combinations minimized the effort needed to do the job.

Visual inspection, the most important element of the sorting operation on the float-roll table, requires varying degrees of effort on the part of sorters. Within certain ranges of rotation speed the sorters found it easy to see the entire surface of the apples, while at higher rotations they had to look more intently and quickly at the doubtful surface areas in order to adequately determine the grade of the apples. Since this phase of the sorting job was not measurable, the best estimate of satisfactory rotation was obtained from the sorters' preferences. The tabulation below shows the range of rotation and forward speeds that the sorters preferred:

Translation speed per minute (feet):	*Rotations per foot (Number)*
25	1. 4–1. 6
30	1. 2–1. 3
35	1. 0–1. 1

Note that the rate of rotation of the apples was about the same for all forward speeds. Thus it is possible on commercial models of the sorting table to install only one variable-speed motor; then, by setting the rotation control at a specific number of rotations per foot for a specific translation speed, the resulting rotations at all other table speeds would be about the same as those preferred by the sorters. Table 10 shows the rotations per foot of a size 125 apple when the speed of the rotational drive (base drive speed) is held constant and the forward speed varied.

TABLE 9.—*Average quality of size 125 apples sorted on float-roll sorting table operated at different translation and rotation speeds* [1]

Number of observations	Apples dumped per hour	Translation speed per minute	Rotations per foot	Average incoming quality [2]	Average outgoing quality [2]
		Feet		*Percent*	*Percent*
3	4, 500	25	1. 0	40	3. 3
4	4, 500	25	1. 4	44	5. 0
6	4, 500	25	1. 8	40	4. 3
2	4, 500	25	2. 3	42	5. 1
4	6, 300	35	. 8	22	3. 2
8	6, 300	35	1. 0	22	2. 5
8	6, 300	35	1. 4	25	3. 2
2	6, 300	35	1. 6	22	5. 0

[1] Size 125 apples are 2¾ inches in diameter.
[2] Percentage of C grade and culls.

TABLE 10.—*Rotations per foot of size 125 apples on a float-roll sorting table for varying translation speeds and constant rotating speeds* [1]

Base drive speeds		Rotations per foot when translation speed is changed to—			
Rotations per foot	Translation speed per minute	20 feet per minute	25 feet per minute	30 feet per minute	35 feet per minute
	Feet				
1.4	25	1. 9	1. 4	1. 0	0. 8
1.2	30	2. 2	1. 6	1. 2	. 9
1.0	35	2. 4	1. 8	1. 3	1. 0

[1] Size 125 apples are 2¾ inches in diameter.

Presenting Fruit in Multiple Rows

Tests were also conducted on the float-roll sorting table to determine the effect that presentation of apples in multiple rows had on efficiency. Results of 10 tests showed that, on the average, 6.0 percent of the fruit leaving the table from 2 rows was below grade, whereas 4.0 percent of the fruit from a single row was below grade.[5]

[5] Apples inspected per sorter per hour, 4,500; percentage of C grade and culls, 40 percent; average rotations per foot 1.4 for 1 row, 2.4 for 2 rows.

The presentation of apples in multiple rows did not facilitate visual inspection. With many types of defects, a close examination was necessary to determine the grade. Although more apples were included in the sorter's cone of vision in 2 rows, she had to closely examine most of the defective apples 1 at a time. The presentation of apples in multiple rows does not appreciably affect the work of closely inspecting the surface of a single apple.

Effect on Other Packing Line Operations

Substituting the float-roll table for another type of table in a packing line increased the rate of output for the entire line. The operations affected by the greater capacity of the float-roll table were: (1) Bringing fruit from storage to packing line, (2) dumping fruit at washer, (3) handling empty boxes, (4) sizing, (5) packing fruit in containers, (6) stamping size and grade on containers, (7) tallying, (8) lidding, (9) labeling, and (10) segregating and moving boxes to storage.

The average increase in production for apples of all sizes was about 45 percent (table 11). This increase was reflected in all packing line operations. For most operations this increase could be handled with the same number of workers. Need of additional labor, if any, would depend largely on the particular plant involved and the methods of performing the operations.

Production rates for the commonly used methods of moving apples from storage to the dumper exceed the sorting rates for the float-roll table. Previous studies disclosed this fact.[6] In some cases an additional part-time worker may be needed to move unpacked boxes from storage to the temporary supply bank near the washer.

When fruit is dumped manually, the dumping rate averages about 300 unpacked boxes of apples per hour. One worker cannot dump enough fruit to maintain the sorting operation at an optimum level. An additional worker, or an automatic dumper, is needed to meet the increased sorting capacity of the float-roll sorting table (fig. 15). The dumping capacity of two workers or an automatic dumper exceeds the sorting capacity of the table except when 15 percent or less fruit is of low grade.

Commonly used methods of handling empty boxes—the 2-wheel hand truck, roller conveyor, overhead monorail conveyor, and industrial forklift

TABLE 11.—*Number of apples inspected per sorter, on a reverse-roll sorting table and float-roll sorting table, for size 100–150 apples of specified qualities* [1]

Percentage of low-grade fruit [2]	Apples inspected per sorter per hour		Difference
	On float-roll table	On reverse-roll table	
			Percent
15	7,164	4,410	62
25	5,302	3,624	46
35	4,500	3,286	37
45	4,056	3,098	31

[1] Size of fruit does not affect capacity when using 8 sorters and sorting 2 grades.

[2] Assumed 5 percent culls.

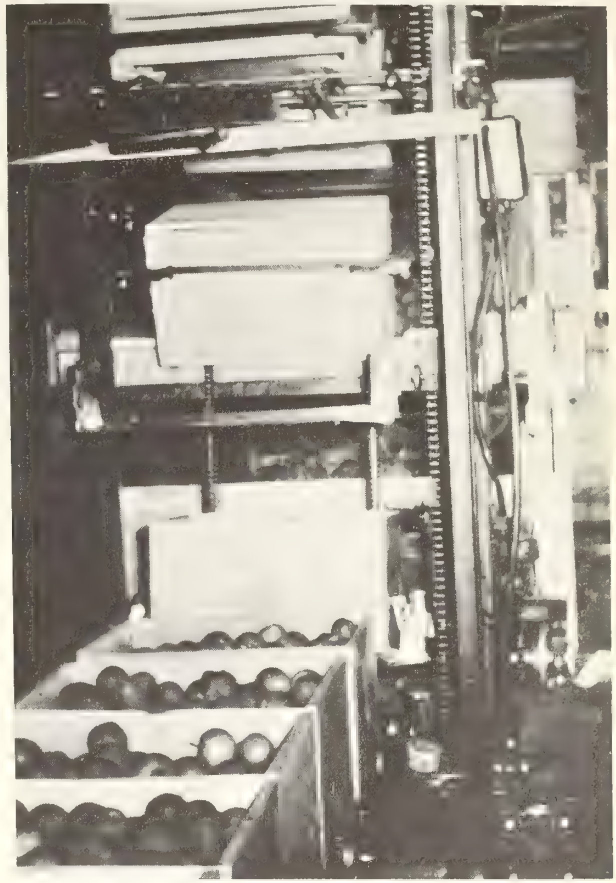

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FIGURE 15.—A mechanical apple dumper.

[6] Carlsen, Earl W., Hunter, D. Loyd, Duerden, Raoul S., and Herrick, Joseph F., Jr., "Apple Handling Methods and Equipment in Pacific Northwest Packing and Storage Houses." U. S. Dept. Agr., Mktg. Res. Rpt. No. 49. June 1953.

truck—have capacities of over 500 boxes per hour.[7] Consequently the increased output of the float-roll table could be handled by any of these methods.

The capacity of a 6-section weight-type sizer is less than the sorting capacity of the float-roll table when less than 15 percent of the fruit is of low grade. For this grade distribution, the rate of sorting must be reduced to the capacity of the sizing equipment.

The capacity of the float-roll sorting table would require more than the usual number of packers. The average hourly packing rate of a packer for size 125 apples is about 18 standard Northwest apple boxes (outside dimensions, 12 by 11 by 19½ inches). Thus, in packing a lot of size 125 apples, containing 15 percent of low-grade apples, 24 packers would be required. This compares with a maximum of 15 packers with a reverse-roll table.[8]

One worker, tallying packed boxes, by lot, grade, variety, and size, has a capacity of about 5,800 boxes per hour. This is well above the sorting capacity of the float-roll table.

The method of conveying packed boxes to the lidding machine and positioning them affects the hourly production rate of lidding. Three general methods and the capacity of each are: [9]

(1) Worker reaches and pulls box from roller conveyor and positions it in lidding machine—338 boxes per hour.

(2) Box is conveyed automatically to machine and worker positions it—383 boxes per hour.

(3) Box is automatically conveyed to and positioned in lidding machine—671 boxes per hour.

The increased output of the float-roll sorting table could be handled only by method No. 3. Another worker, to deliver the unlidded packed boxes of apples to the lidder, would be needed for methods No. 1 and No. 2.

The capacity of one worker applying labels to the ends of packed boxes is 641 boxes per hour. Thus, the rate of the labeling operation would be adequate to handle the increased capacity of the float-roll table (see footnote 9).

The prevailing methods used to segregate and move packed boxes from the packing room to storage have an average production rate of 400 to 450 boxes per hour, depending upon the grouping of sizes in the stacks. This is very near the capacity of the float-roll table.

Bruise Studies on the Float-Roll Sorting Table

Tests were conducted on the float-roll and reverse-roll sorting tables to determine the extent of bruise damage caused by the sorting operation. For these tests, 400 boxes of Standard Delicious apples were carefully harvested and placed in containers, then in cold storage. The fruit was picked about 10 days before the peak of the commercial harvest.

Before the tests were started, this bruise-free fruit was divided into 2 lots, 1 for each packing line. The float-roll sorting table was operated at a forward speed of 30 feet per minute and the reverse-roll table at 23 feet per minute. On both tables sorters handled the fruit in the usual manner. The fruit was dumped and washed, then moved over the sorting tables and directly onto feed belts leading to the sizers. While the fruit was being run over the lines, samples were drawn as the apples emerged from the washers and as they reached the end of the sorting tables.

Table 12 shows a comparison of bruise damage occurring on the 2 sorting tables tested. The total bruise damage for the float-roll sorting table was 17.9 bruises per 100 apples tested. The percentage of sound apples at the end of the float-roll table was 84.6 percent; this compares with 86.0 percent for the reverse-roll table. From the data it can be concluded that neither sorting table causes a significant amount of bruise damage, and that there is no significant difference in bruising on the 2 sorting tables.

TABLE 12.—*Comparison of bruise damage tests made on the float-roll and reverse-roll sorting tables*

Equipment	Bruises per 100 apples			Stem punctures per 100 apples	Percentage remaining sound
	½ to ¾ inch long	¾ inch and over	Total		
Reverse-roll table	13. 4	1. 2	14. 6	0	86. 0
Float-roll table	16. 0	1. 9	17. 9	. 6	84. 6
Difference	2. 6	. 7	3. 3	. 6	1. 4

[7] Hunter, D. L., Duerden, R. S., Kafer, F., and Herrick, J. F., Jr., "Handling Empty Apple Boxes in Pacific Northwest Packing and Storage Houses." U. S. Dept. Agr., Mktg. Res. Rpt. No. 71, June 1954.

[8] Computed from data appearing in table 11.

[9] From unpublished studies, to be released later, of other packing room operations.

Cost data obtained from a number of apple packinghouses in the Pacific Northwest showed minor differences in costs of owning and operating four types of sorting tables. Differences in costs were due in large part to the number of workers and how they were used. Most packing plants adhere closely to the hourly wage scales established between the workers' union and packing plant operators. Differences in total sorting costs, therefore, are attributed to variations in efficiency of labor, since the costs of owning and operating sorting equipment and the hourly wage rates for the plants studied were approximately the same.

Equipment Costs

Differences in ownership costs were small for the various sorting tables (table 13). The initial cost of the belt-type table, the least expensive of the 4 sorting tables, is $1,211, or only $232 more than the reverse-roll sorting table. Because of additional

TABLE 13.—*Comparative ownership and operation costs for four types of apple sorting tables in Pacific Northwest apple packing and storage plants*

Equipment	Replacement cost [1]	Ownership cost per year				Operation cost per year			Total ownership and operation costs per year	Cost per hour of use [4]
		Depreciation [2]	Interest at 5 percent	Insurance and taxes at 2 percent	Total	Gas, oil, and electricity [3]	Maintenance	Total		
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Belt (return flow) table:										
Table	1,017.00									
Installation	48.00									
Motor	146.30									
Total	1,211.30	80.75	30.28	24.23	135.26	4.50	3.00	7.50	142.76	0.24
Spiral-roll table:										
Table	1,050.00									
Installation	48.00									
Motor	146.30									
Total	1,244.30	82.95	31.11	24.89	138.95	4.50	12.00	16.50	155.45	.26
Reverse-roll table: [5]										
Table	1,232.50									
Installation	28.00									
Motor	183.00									
Total	1,443.50	96.23	36.09	28.87	161.19	1.50	3.00	4.50	165.69	.28
Float-roll table: [6]										
Table	1,184.00									
Installation	28.00									
Motors (2)	366.00									
Total	1,578.00	105.20	39.45	31.56	176.21	3.00	3.00	6.00	182.21	.30

[1] Replacement cost in Pacific Northwest.
[2] Based on an assumed life of 15 years.
[3] Average cost in industry for electricity is 1 cent per kilowatt hour.
[4] Computed on basis of 600 hours of operation per year and a packout of 126,000 boxes.
[5] Same as improved reverse-roll table.
[6] Developed and constructed as part of this study.

materials and labor, the estimated initial cost of the float-roll table, $1,578, is about $367 more than the belt-type sorting table.

Yearly costs of ownership and operation include depreciation, taxes, insurance, maintenance, repair, and power. Estimated total ownership, or fixed, cost of $176 for the float-roll table is only $41 greater than that for the belt table, and only $15 greater than that for the reverse-roll table. Depreciation is the largest of the fixed-cost items for all tables. Operation costs, consisting of gas, oil, electricity, and maintenance costs, are greatest for the spiral-roll table ($16.50) and least for the reverse-roll table ($4.50). Estimated operation cost for the float-roll table is $6.00 per year. The influence of equipment ownership and operation costs on total sorting costs is rather small.

Labor Costs

Labor costs comprise over 95 percent of total sorting costs. Consequently, the relative efficiency of sorters is largely responsible for differences in total sorting costs for different types of tables. As mentioned previously, sorting efficiency depends mainly on the quality and size of the fruit. Labor costs of sorting for the 5 types of sorting tables were compared under constant conditions of size and quality.

Table 14 shows labor costs per 1,000 boxes of unpacked apples for 5 sorting tables when sorting fruit of 3 sizes and 3 qualities.[10] Because all apples must be lifted from the belt table, man-hour requirements to sort 1,000 boxes of fruit into 3 grades on this table are greater than for any of the other tables. Labor costs for sorting the 3 qualities of fruit on a belt table were almost twice those for the float-roll table. For sorting 1,000 boxes of apples into 3 grades, with 40 percent of the fruit lifted from the table, the cost of labor on the float-roll table was $13.29 more for size 150 apples than for size 100 apples. On the improved reverse-roll table, the difference was $15.67; on the standard reverse-roll table, $17.57; on the spiral-roll table, $17.91; and on the belt table, almost $23. The difference in costs for the two sizes was smaller for the float-roll table than for the other tables, largely because of the use of individual lanes for sorters and cull disposal chutes.

[10] Labor charges were converted to a basis of 1,000 unpacked boxes by use of adjusted rates of sorting efficiency developed in the studies for each type of table.

TABLE 14.—*Comparative labor costs for sorting apples of specified sizes and qualities into 3 grades on 5 types of sorting tables* [1]

Equipment and apple size	Cost per 1,000 boxes of loose fruit for specified qualities [2]		
	30 percent	40 percent	50 percent
	Dollars	*Dollars*	*Dollars*
Belt table:			
100	45.85	48.13	49.58
125	57.42	59.80	61.70
150	69.04	72.05	74.36
Spiral-roll table:			
100	34.32	35.80	36.71
125	43.12	44.61	45.85
150	51.78	53.71	55.24
Reverse-roll table:			
100	33.05	35.15	36.60
125	41.28	43.94	45.67
150	49.79	52.72	54.72
Improved reverse-roll table:			
100	28.22	31.10	33.23
125	35.37	38.79	41.57
150	42.34	46.77	49.79
Float-roll table:			
100	24.16	26.85	28.78
125	30.21	33.43	36.13
150	36.25	40.14	43.28

[1] Eight sorters per sorting table at $1.25 per hour per sorter, and half the time of one supervisor at $1.75 per hour.

[2] Percentage of low-grade fruit and culls lifted from table.

Possible Savings by Use of New Float-Roll Table

In preceding sections, costs of labor and equipment were shown for sorting 1,000 boxes of unpacked apples for 5 sorting tables. Presented in this section are estimated annual labor and equipment costs for inspecting and grading different volumes of fruit for the 5 tables. Also shown in this section is the approximate time required to recover the initial cost of a new float-roll table from expected savings, when the new float-roll table is substituted for a belt, spiral-roll, reverse-roll, or improved reverse-roll table.

Table 15 shows the average daily output for 5 apple sorting tables, the number of days required to grade and inspect specified volumes, total costs, differences in costs of the float-roll table and the other 4 tables, and the approximate number of years needed to recover the initial cost of the float-roll table from estimated savings resulting from lower sorting costs. Assuming that 8 sorters work

TABLE 15.—*Annual labor and equipment costs for 5 sorting tables for sorting size 125 apples when 40 percent of apples are of low grade, for specified volumes*

Volume and sorting table	Daily sorting rate [1]	Operating period [2]	Labor cost [3]	Equipment cost: Initial [4]	Equipment cost: Ownership [5]	Equipment cost: Operation [6]	Equipment cost: Total ownership and operation	Total labor and equipment cost	Difference between total cost and cost of float-roll table	Estimated time required to recover costs of new float-roll table [7]
	Boxes	*Days*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Years*
50,000 boxes:										
1 float-roll	2, 602	20	1, 740	1, 578. 00	176. 21	1. 20	177. 41	1, 917. 41	....	....
1 improved reverse-roll	2, 242	23	2, 001	1, 443. 50	161. 19	1. 50	162. 69	2, 163. 69	246. 28	6. 5
1 reverse-roll	1, 980	26	2, 262	1, 443. 50	161. 19	1. 86	163. 05	2, 425. 05	507. 64	3. 5
1 spiral-roll	1, 950	26	2, 262	1, 244. 30	138. 95	7. 26	146. 21	2, 408. 21	490. 80	3. 5
1 belt	1, 455	35	3, 045	1, 211. 30	135. 26	3. 50	138. 76	3, 183. 76	1, 266. 35	1. 5
100,000 boxes:										
1 float-roll	2, 602	39	3, 393	1, 578. 00	176. 21	2. 40	178. 61	3, 571. 61	....	....
1 improved reverse-roll	2, 242	45	3, 915	1, 443. 50	161. 19	3. 00	164. 19	4, 079. 19	507. 58	3. 5
1 reverse-roll	1, 980	51	4, 437	1, 443. 50	161. 19	3. 72	164. 91	4, 601. 91	1, 030. 30	2
1 spiral-roll	1, 950	52	4, 524	1, 244. 30	138. 95	14. 52	153. 47	4, 677. 47	1, 105. 86	1. 5
1 belt	1, 455	69	6, 003	1, 211. 30	135. 26	7. 00	142. 26	6, 145. 26	2, 573. 65	1
200,000 boxes:										
2 float-roll	5, 204	39	6, 786	3, 156. 00	352. 42	4. 80	357. 22	7, 143. 22	....	....
2 improved reverse-roll	4, 484	45	7, 830	2, 887. 00	322. 38	6. 00	328. 38	8, 158. 38	1, 015. 16	3. 5
2 reverse-roll	3, 960	51	8, 874	2, 887. 00	322. 38	7. 44	329. 82	9, 203. 82	2, 060. 60	2
2 spiral-roll	3, 900	52	9, 048	2, 488. 60	277. 90	29. 04	306. 94	9, 354. 94	2, 211. 72	1. 5
2 belt	2, 910	69	12, 006	2, 422. 60	270. 52	14. 00	284. 52	12, 290. 52	5, 147. 30	1
400,000 boxes:										
3 float-roll	7, 806	52	13, 572	4, 734. 00	528. 63	9. 36	537. 99	14, 109. 99	....	....
3 improved reverse-roll	6, 726	60	15, 660	4, 330. 50	483. 57	11. 70	495. 27	16, 155. 27	2, 045. 28	2. 5
3 reverse-roll	5, 940	68	17, 748	4, 330. 50	483. 57	14. 58	498. 15	18, 246. 15	4, 136. 16	1. 5
3 spiral-roll	5, 850	69	18, 009	3, 732. 90	416. 85	57. 42	474. 27	18, 483. 27	4, 373. 28	1
3 belt	4, 365	92	24, 012	3, 633. 90	405. 78	27. 60	433. 38	24, 445. 38	10, 335. 39	. 5

[1] Boxes of loose fruit.

[2] Time required to complete sorting job.

[3] Cost of 8 sorters per table, computed at \$1.25 per hour, per sorter, for an 8-hour day plus one-half the time of a supervisor at \$1.75 per hour. Daily labor cost × operating period = labor cost.

[4] Total cost, installed, in Washington State.

[5] Computed as follows: Depreciation based on 15-year life, interest at 5 percent, and taxes and insurance at 2 percent.

[6] Includes maintenance, water, oil, and electricity at 1 cent per kilowatt hour.

[7] Assumed that sorting tables other than float-roll table have no book value (fully depreciated). Computed as follows: Initial cost of new float-roll table ÷ ("Difference" − depreciation and interest cost of table) = estimated number of years required to recover investment in new float-roll table.

at each table, and that the float-roll table is equipped with lanes and cull disposal chutes, the sorting time of the float-roll table is a little more than half that of the belt table for volumes of 50,000, 100,000, 200,000, and 400,000 boxes of unpacked fruit; hence sorting labor costs for the belt table are substantially higher than for the float-roll table. Assuming that 2 tables are used to sort 200,000 boxes and 3 to sort 400,000 boxes, the operating periods for sorting the 4 volumes on spiral-roll and reverse-roll tables are about a third greater than for float-roll tables. If individual work lanes for sorters and cull disposal chutes are added to the standard reverse-roll table, and control is exercised over the dumping rate (fairly high rate for good fruit and lower rate for poor fruit), the operating period for sorting can be reduced by about 13 percent.

Replacing a belt, spiral-roll, or reverse-roll table with a float-roll table would reflect economies to other packing house operations. For example, the daily packout could be increased in many plants, since the sorting operation sets the pace for the entire packing line operation; also, better use could be made of cold storage space because 3 boxes of packed fruit are equivalent to 4 boxes of unpacked fruit. The number of intraplant handlings of boxes of unpacked fruit may be reduced by increasing the volume moved directly from growers' trucks to the packing room, rather than into cold storage. The extent of these savings is difficult to measure in dollars and cents; also, they would vary considerably between individual plants.

Shown in the last column of table 15 is the estimated time required to recover the initial cost of a new float-roll table from lower costs of labor and equipment (savings) when this table is used to replace any 1 of the other 4 sorting tables. To obtain the estimated time required to recover the initial costs of the float-roll table, ownership costs of depreciation and interest for the belt, spiral-roll, reverse-roll, and improved reverse-roll tables were deducted from "differences" from the float-roll table. This, in effect, assumes that these 4 tables are fully depreciated (have no book value).

A plant operator sorting 50,000 boxes of unpacked apples a year on a belt table would recover the initial cost of a new float-roll table of $1,578.00 in about 1½ years. For sorting volumes of 100,000 and 200,000 boxes on belt tables, the costs of new float-roll tables would be recovered in not more than 1 year's operation. Replacing belt sorting tables in a plant handling 400,000 boxes a year, the initial cost of 3 float-roll tables would be recovered in about half a year. To recover initial cost of a float-roll table when replacing a spiral-roll table in a 50,000-box plant, about 3½ years would be needed, about 1½ years for 100,000- and 200,000-box volumes, and not more than 1 year for sorting an annual volume of 400,000 boxes. Slightly longer periods would be needed to recover initial costs of float-roll tables when they replace reverse-roll tables at all volumes considered. For sorting 50,000 boxes of unpacked fruit a season, the initial cost of a float-roll table, when replacing an improved reverse-roll table, would be recovered in about 6½ years, for volumes of 100,000 and 200,000 boxes about 3½ years, and for 400,000 boxes not more than 2½ years.

Before replacing a fully depreciated sorting table with a new float-roll table, consideration should be given to other elements of cost that may be involved. Some packing plants, in order to use the extra capacity of the new float-roll table, would have to invest additional capital in more efficient sizing and packing equipment. Whether or not additional capital should be invested in new equipment would depend largely on an estimate of whether future volume of business will increase, decrease, or remain the same. Small-volume packers—under 75,000 boxes—before investing additional capital in new equipment should give consideration to adopting more efficient sorting methods and making changes on present sorting equipment, such as those made on the reverse-roll sorting table.

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